15058

Pigeonite Basalt

2672 grams

Figure 1: Photo of mare basalt 15058 (before dusting). NASA S71-44205. Sample is shaped like a brick about 6 inches long and 3 inches high.

Note: see also figures 17 and 18

Introduction

15058 is a quartz-normative mare basalt with abundant elongate pyroxene crystals (figure 1). It has been dated at 3.4 b.y. with an exposure age of ~ 135 m.y.

15058 is one of the largest basalts returned from the moon, but its lunar orientation is not known with much certainty. The catalog records a few zap pits of the B1, W1and E1 surface, none on T1, N1 or S1. The sample has been shown to have a multistage exposure history (Eugster et al. 1984) and has been used for numerous studies of cosmic ray tracks.

Petrography

Ryder (1985), Bence and Papike (1972), Brown et al. (1972) and Gay et al. (1972) and Juan et al. (1972) describe the texture of 15058 and classify it as a pigeonite basalt. Large phenocrysts of pigeonite are green in the cores with brown rims. Although Rhodes and Hubbard (1973) reported rare olivine, the rock is quartz-normative. Olivine is restricted to cores of large pigeonite. Clusters of radiating plagioclase crystals are common (figure 3). Vugs contain pyroxene and plagioclase with diktytaxitic texture.

Mineralogical Mode of 15058

	Sample catalog Butler 1971	Rhodes and Hubbard 1973	Juan et al. 1972
Olivine	tr.	1.8	
Pyroxene	71	66.3	72
Plagioclase	24	27.1	22
Opaques	2-3	2.8	2
Silica	1	2.1	3
Other	1		

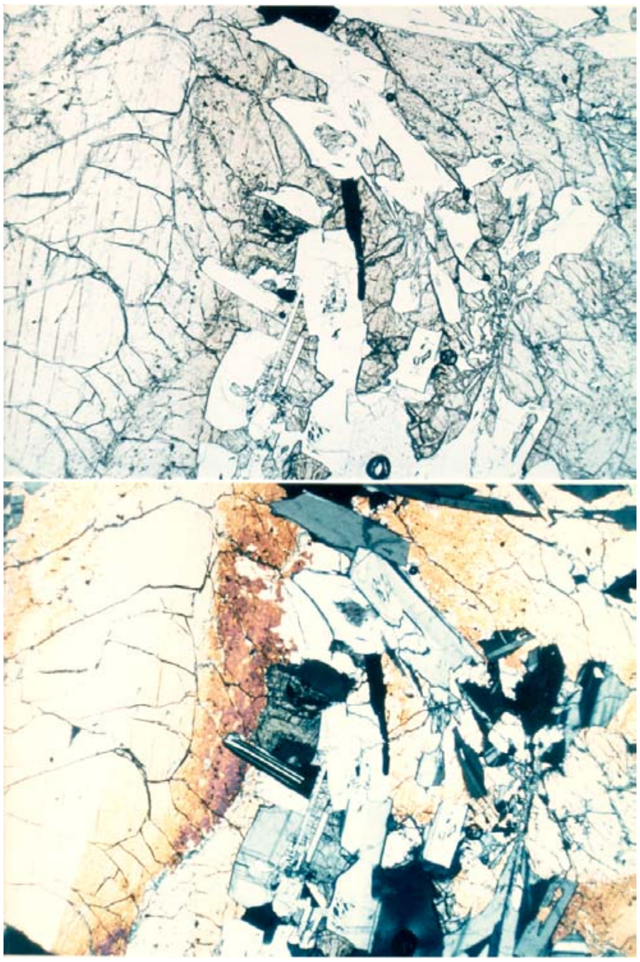


Figure 2: Thin section photomicrgraphs of 15058 showing large pyroxene phenocryst (left) and subophitic texture. Top is plane polarized light; bottom is crossed polarized. NASA S71-51746 and 747. Scale about 1 mm.

Figure 3: Low magnification photo of microscope slide showing elongate pyroxene crystals and radiating plagioclase laths in 15058,128. Scale is about 1 cm.

Papike et al. (1972) note that exsolution features are consistent with "slow cooling". The cooling rate of 15058 and other basalts was studied experimentally by Grove and Walker (1977), Lofgren et al. (1975) and others.

Mineralogy

Pyroxene: The pyroxenes in 15058 are long – up to 2 cm in length – and highly zoned. Bence and Papike (1972) reported analyses of pyroxene in 15058 (figure 5). Papike et al. (1976) reported the cell dimensions of pyroxene crystals. Burns et al. (1972) discussed the charge balance and color of transition elements. Papike et al. (1972) discuss pyroxene exsolution and note that the coes of large pigeonite are not exsolved.

Plagioclase: Hollow plagioclase laths can be seen in thin section (figure 2). Gay et al. (1972), Juan et al. (1972) and Wenk et al. (1973) reported plagioclase composition An_{80-90}.

Ilmenite: Taylor et al. (1972) have used Zr in ilmenite as a measure of cooling rate and Engelhardt (1979) has determined the paragenesis of the rock using shape of ilmenite.

Spinel: Haggerty (1972) found that the spinel in 15058 was limited to ulvospinel.

Phosphates: McCubbin et al. (2010) have found that most of the phosphate grains in 15058 are fluoroapatite with minor chloroapatite and trace water (~2400 ± 1100 ppm H_2O).

Chemistry

O'Kelley et al. (1972) reported the K, Th and U content of the whole sample. The bulk composition was determined by LSPET (1972), Willis et al. (1972), Fruchter et al. (1973), Helmke et al. (1973), Rhodes et al. (1973). Wolf et al. (1979) determined trace elements (table 1). The composition is like that of other Apollo 15 basalts (figures 7 and 8). Gibson et al. (1975) determined the sulfur content (960 ppm).

Gibson and Moore (1972) determined the thermal release, outgassing of H_20, CO_2 and other species (figure 12).

note: see also figure 19

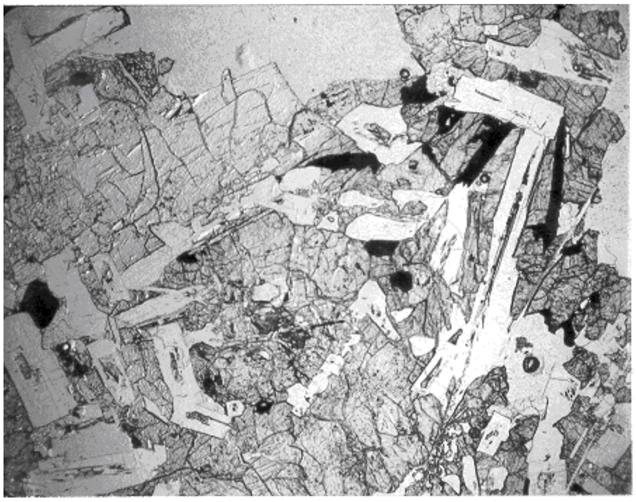


Figure 4: Closeup photomicrograph of thin section 15058,14 illustrationg hollow plagioclase needles (straws). Scale about 3 mm.

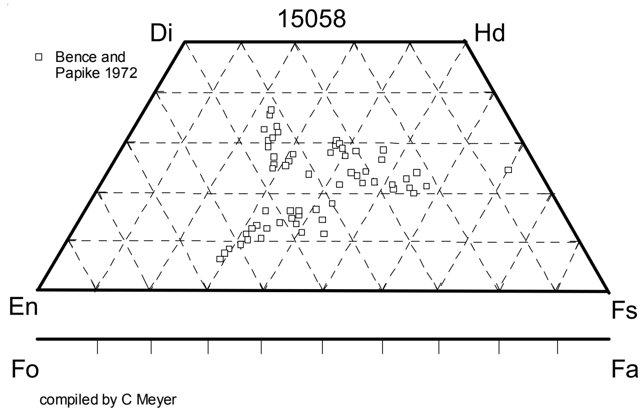


Figure 5: Composition of pyroxene in 15058.

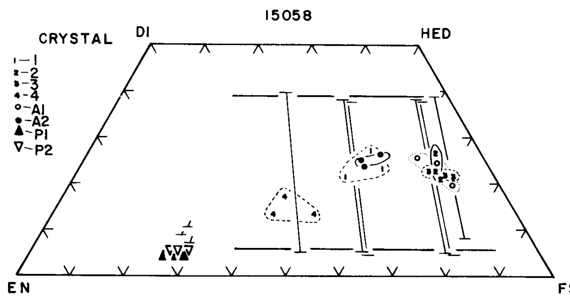


Figure 6: Exsolution of pyroxene in 15058 (from Papike et al. 1972).

Radiogenic age dating

Husain (1974) and Birck et al. (1975) determined the crystallization age of 15058 by Ar/Ar plateaus and Rb/Sr ischrons (figures 9 and 10).

Cosmogenic isotopes and exposure ages

Eldridge et al. (1972) determined cosmic ray induced activity of ^{22}Na = 26 dpm/kg, ^{26}Al = 62 dpm/kg and ^{54}Mn = 27 dpm/kg.

Eugster et al. (1984) were able to separate the solar cosmic ray effects at the surface from the galactic cosmic ray effects at depth in 15058. They found that 15058 must have had a multistage exposure history, because ^{81}Kr was found to significantly increase near the surface (figure 11) while ^{83}Kr are constant with depth. This would be explained by 15085 having received most of its cosmic ray irradiation in a "shielded location" (beneath the regolith) and finally being exposed to solar irradiation for the last million years right at the lunar surface. Eugster et al. also found that ^{81}Kr, along with ^{3}H (tritium), was enhanced in the surface.

Other Studies

Sato (1973) determined the intrinsic oxygen fugacity of 15058. Epstein and Taylor (1972) determined the composition of oxygen, silicon isotopes of mineral separates.

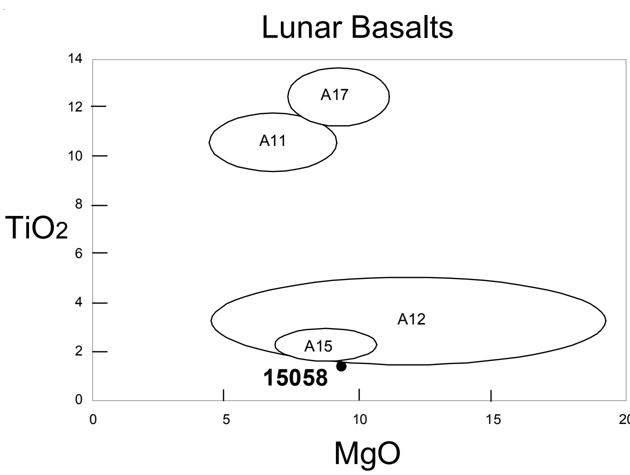


Figure 7: Chemical composition of 15058 compared with that of other lunar basalts.

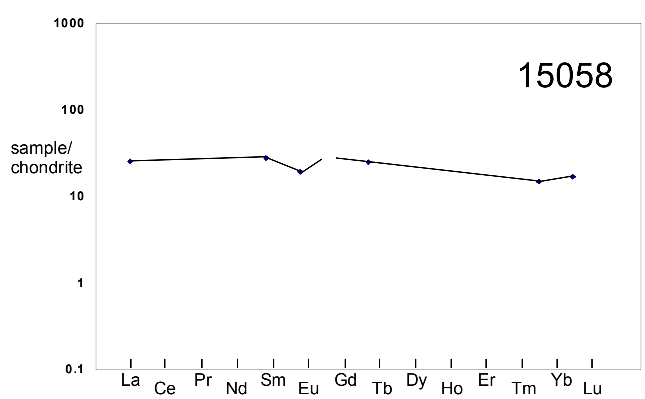


Figure 8: Normalized rare-earth-element composition of 15058 (data from Fruchter et al. 1973).

Table 1. Chemical composition of 15058.

reference	O'Kelly 72		Rhodes 73		Willis 72		Fruchter73		Wolf 79		Helmke73	
weight			A15PET72								1.34 g	
SiO2 %			47.81	(b)	48.47	(b)						
TiO2			1.77	(b)	1.6	(b)	1.8	(c)				
Al2O3			8.87	(b)	8.9	(b)	9.3	(c)				
FeO			19.97	(b)	19.75	(b)	20.1	(c)				
MnO			0.28	(b)	0.274	(b)					0.26	(c)
MgO			9.01	(b)	9.56	(b)						
CaO			10.32	(b)	10.23	(b)						
Na2O			0.28	(b)	0.28	(b)	0.29	(c)				
K2O	0.0486	(a)	0.03	(b)	0.038	(b)						
P2O5			0.08	(b)	0.049	(b)						
S %			0.07	(b)	0.057	(b)						
sum												
Sc ppm							46	(c)				
V												
Cr					4516	(b)	2865	(c)				
Co							42	(c)				
Ni									50	(d)	31	(c)
Cu												
Zn									0.94	(d)		
Ga												
Ge ppb									6.47	(d)		
As												
Se									56	(d)		
Rb					<2	(b)			0.646	(d)		
Sr			101		99.2	(b)					107	(c)
Y					21.1	(b)						
Zr			98		70.9	(b)						
Nb					4.9	(b)						
Mo												
Ru												
Rh												
Pd ppb									< 0.51	(d)		
Ag ppb									0.27	(d)		
Cd ppb									3.35	(d)		
In ppb									0.4	(d)		
Sn ppb									83	(d)		
Sb ppb									0.43	(d)		
Te ppb									2	(d)		
Cs ppm									0.0267	(d)		
Ba					49	(b)					62	(c)
La							6	(c)			5.58	(c)
Ce											14.5	(c)
Pr												
Nd											10.9	(c)
Sm							4.1	(c)			3.9	(c)
Eu							1.08	(c)			0.908	(c)
Gd											5	(c)
Tb							0.9	(c)			0.87	(c)
Dy											5.59	(c)
Ho											1.1	(c)
Er											3.2	(c)
Tm												
Yb							2.5	(c)			2.54	(c)
Lu							0.43	(c)			0.388	(c)
Hf							2.6	(c)				
Ta							0.46	(c)				
W ppb												
Re ppb									0.006	(d)		
Os ppb									0.02	(d)		
Ir ppb									0.0063	(d)		
Pt ppb												
Au ppb									0.081	(d)		
Th ppm	0.52	(a)										
U ppm	0.13	(a)							0.089	(d)		

technique: (a) radiation counting, (b) XRF, (c) INAA, (d) RNAA

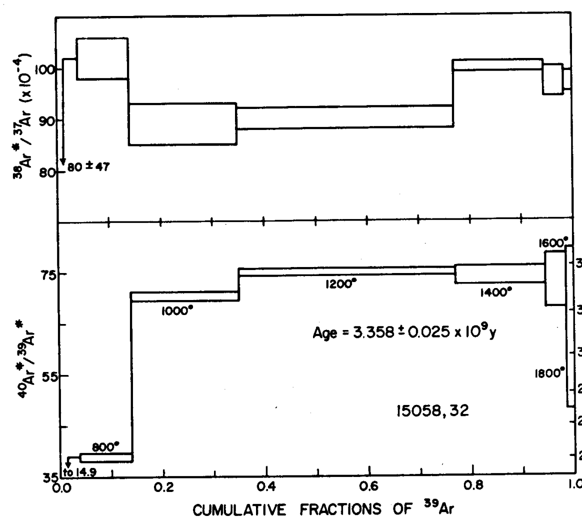


Figure 9: Ar/Ar age dating plateau diagram for 15058 from Husain (1974).

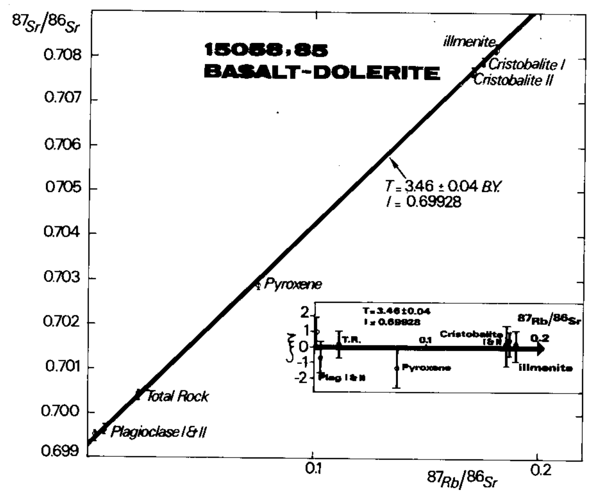


Figure 10: Rb/Sr mineral isochron determined by Birck et al. (1975).

Summary of Age Data for 15058

	Ar/Ar	Rb/Sr
Husain 1974	3.358 ± 0.025 b.y.	
Birck et al. 1975		3.46 ± 0.04

Note: Be careful with these old decay constants.

Abu-Eid et al (1973), Burns et al. (1973) and Huffman et al. (1972, 1974) collected Mossbauer spectra. Charette and Adams (1975) collected IR spectra

Nagata et al. (1972, 1973, 1975), Banarjee and Mellema (1974) and Collinson et al. (1975) have reported on the magnetic properties of 15058. Mitzutani and Newbigging (1973) have determined the seismic velocity in 15058 and Simmons et al. (1975) have investigated the microcracks that greatly influence the physical properties. Schwerer et al. (1974) have investigated the electrical conductivity.

Bhandari et al. (1972, 1973), Poupeau et al. (1972), Fleischer et al. (1973) and Crozaz et al. (1974) have studied the cosmic ray tracks in 15058.

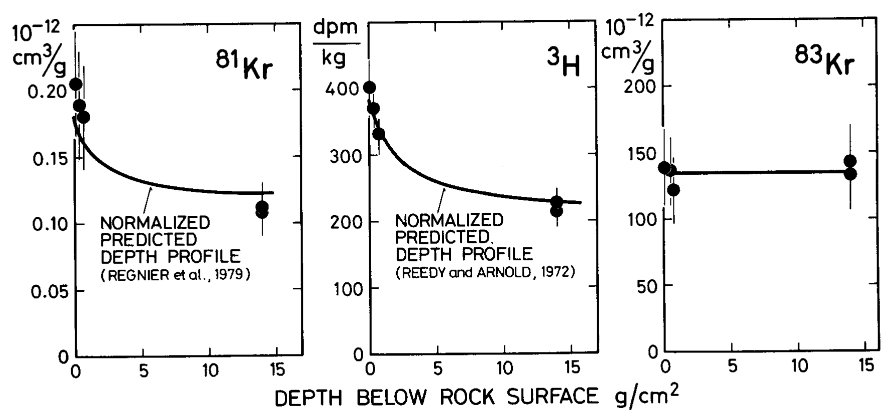


Figure 11: Rare gas depth profile by Eugster et al. 1984 showing variation of isotopic ratios due to bombardment by solar and cosmic rays.

Table 2	U ppm	Th ppm	K ppm	Rb ppm	Sr ppm	Nd ppm	Sm ppm	technique
Birck et al. 1975			330	0.8	99			IDMS
O'Kelley et al. 1973	0.13	0.52	403					counting
Snyder et al. 1998				1.23	110	15.7	5	IDMS
Wolf et al. 1979	0.089			0.646				RNAA

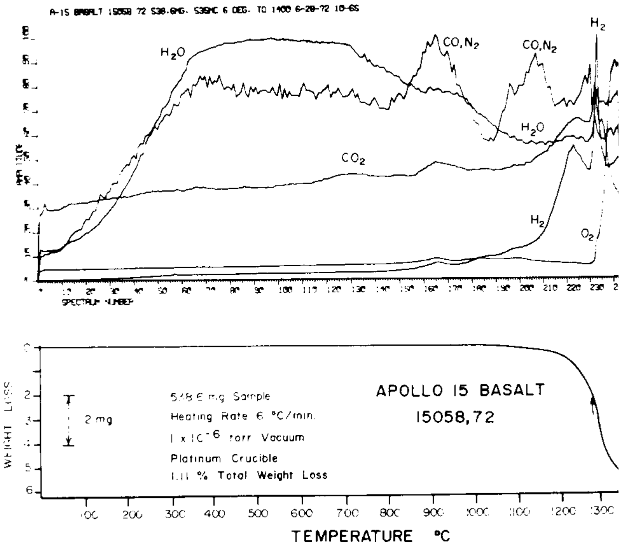


Figure 12: Gas evolved from 15058 on heating (by Gibson and Moore 1972).

Processing

First a long slab was cut (figure 15), then a compound slab was cut at right angles by cutting slabs from each side piece (figure 16). A long thin column was cut from the center of the first slab (,32). This sample was much allocated, especially to science labs wishing to study "physical properties". There are 18 thin sections of 15058.

Several pieces of 15058 have been allocated for public display (figure 13). One is at the NASA AMES Research Center in California, a second at the NASA Kennedy Space Center in Florida, a third at the NASA Lewis Research Center and a fourth is held at JSC PAO.

Additional detailed information is found in the catalog by Ryder (1985).

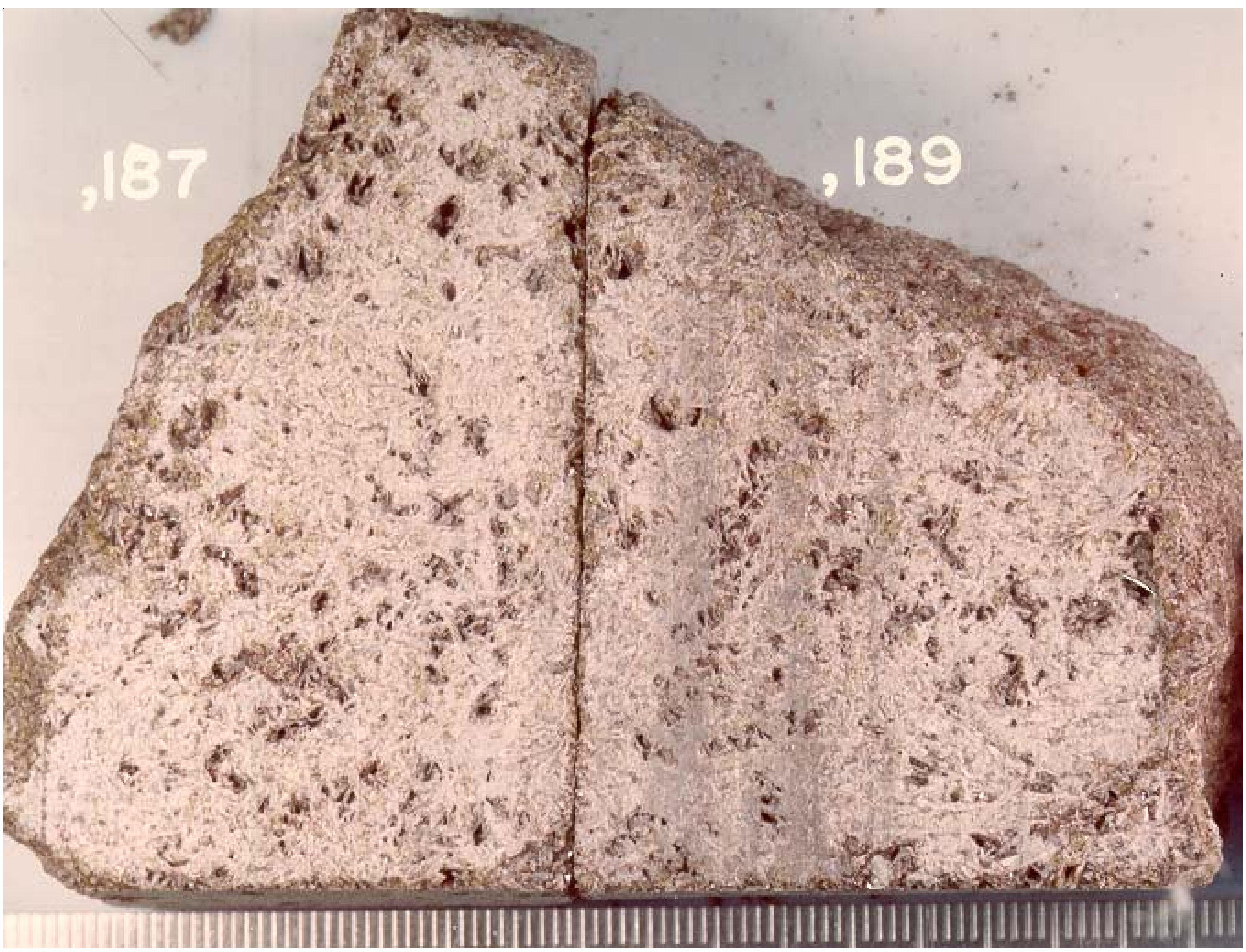


Figure 13: Interior sawn sufaces of 15058. NASA S76-24636. Note long pyroxene needles extending through vugs with diktytaxitic texture. Scale is mm. These are two of the samples on public display.

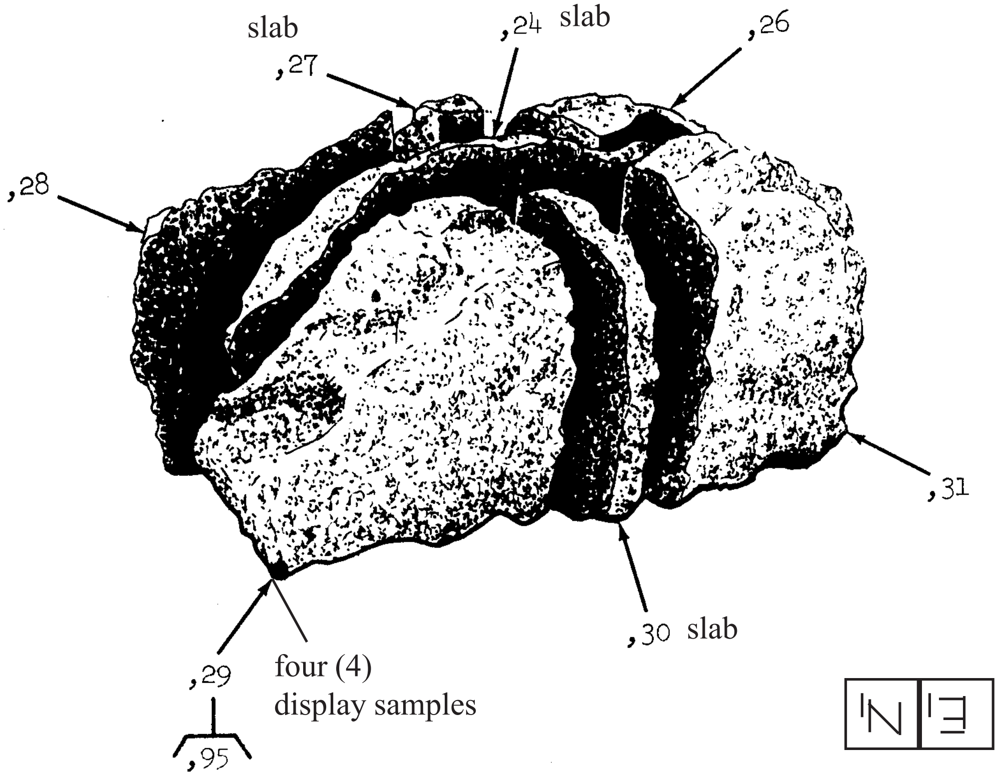
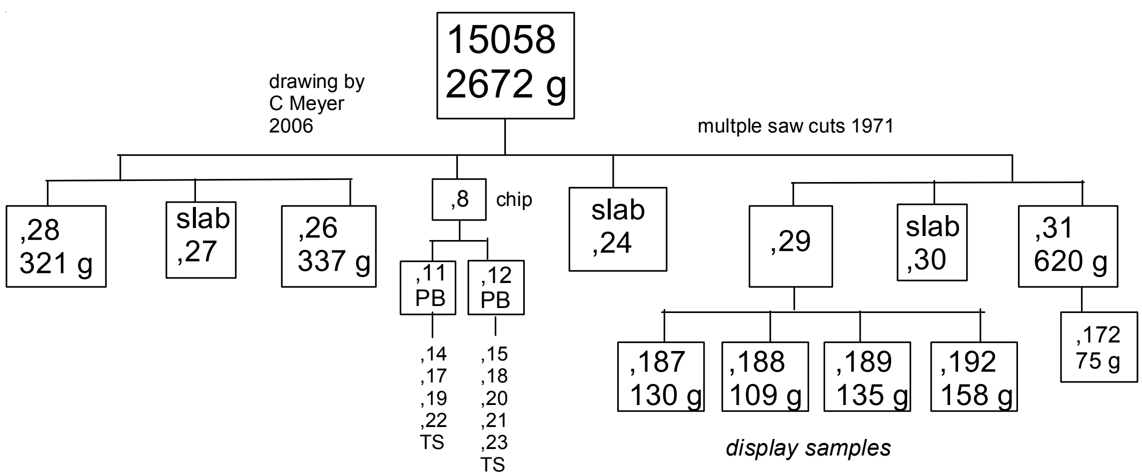


Figure 14: Exploded parts diagram for 15058 showing how two slabs, at right angles, were cut. Large slab ,24 was cut N-S through sample, followed by slices ,27 and ,30 cut E-W from ends.



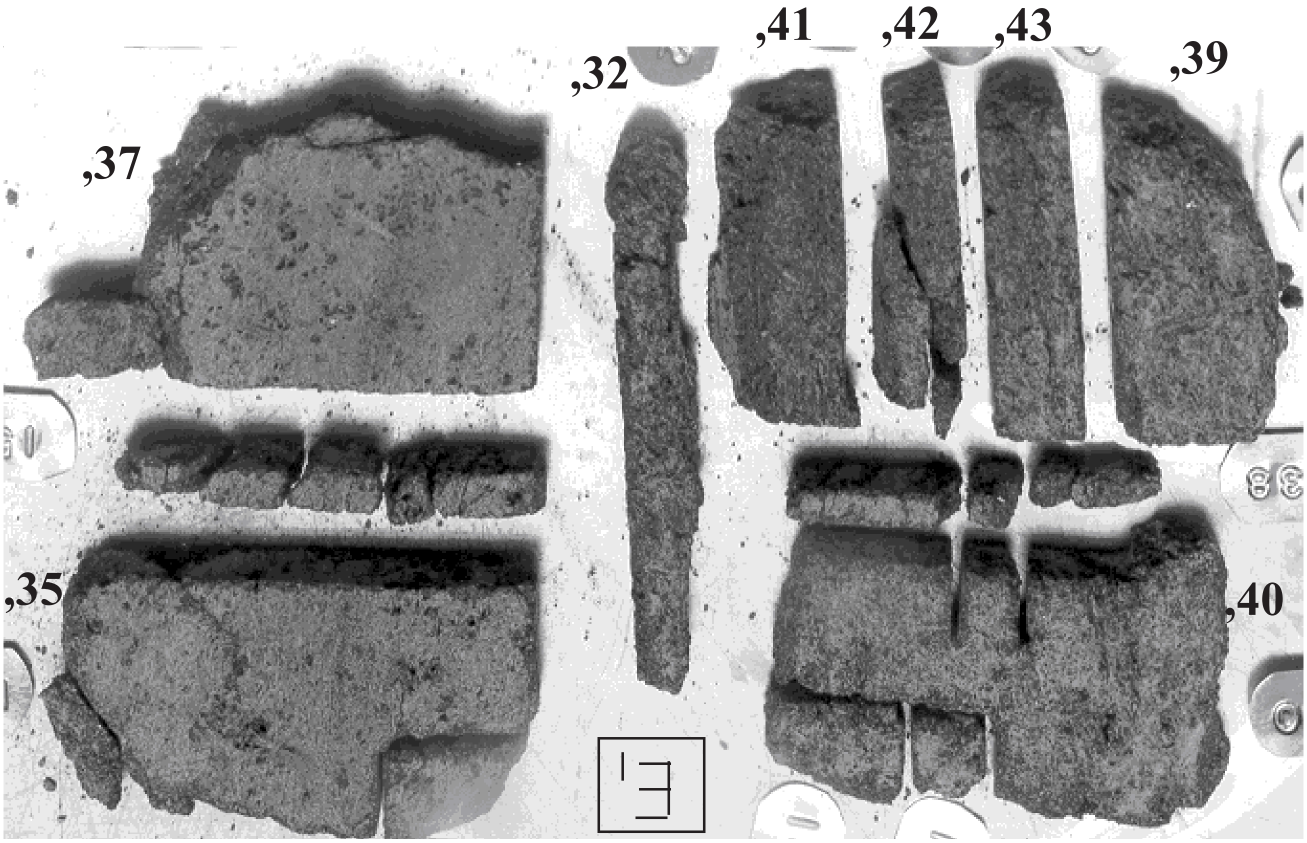
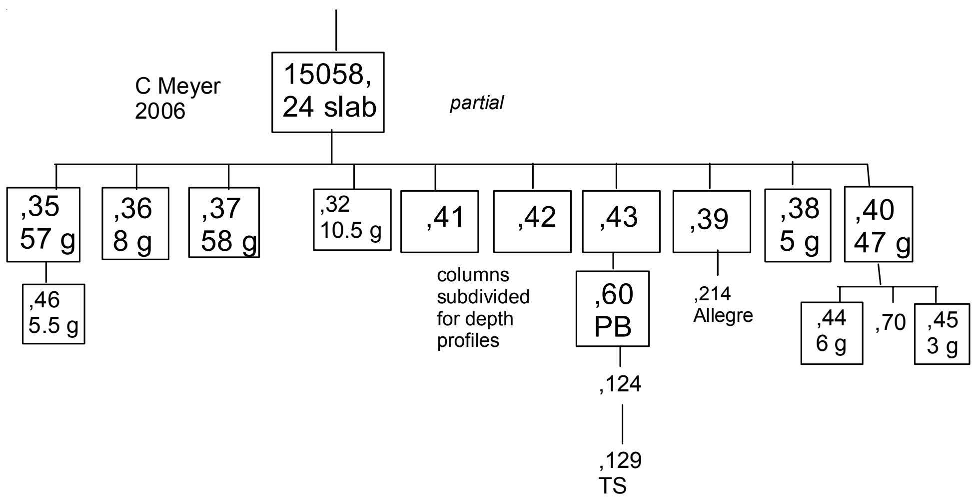
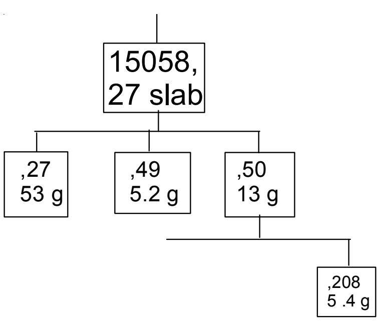
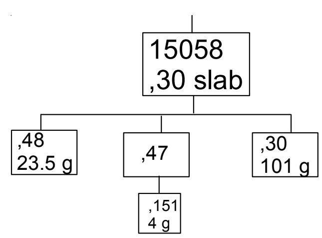


Figure 15: First slab (,24) cut lengthwise through 15058. Columns ,41 ,42 ,43 were further subdivided to provide samples with known depth profiles. NASA S72-15241. Central column not allocated. End piece ,39 was substantially subdivided for most allocations (including age dating by Birck et al.)







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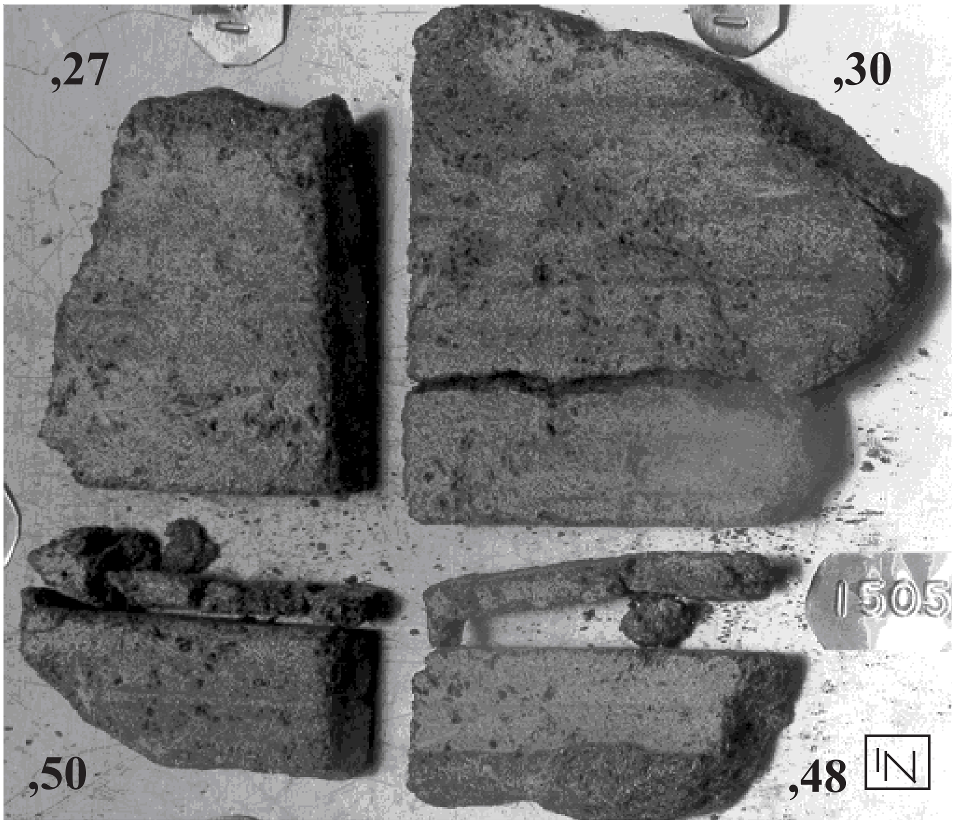

Figure 16: Second (,27) and third (,30) slabs cut at right angles through 15058 (see figure 14). NASA S71-60669.

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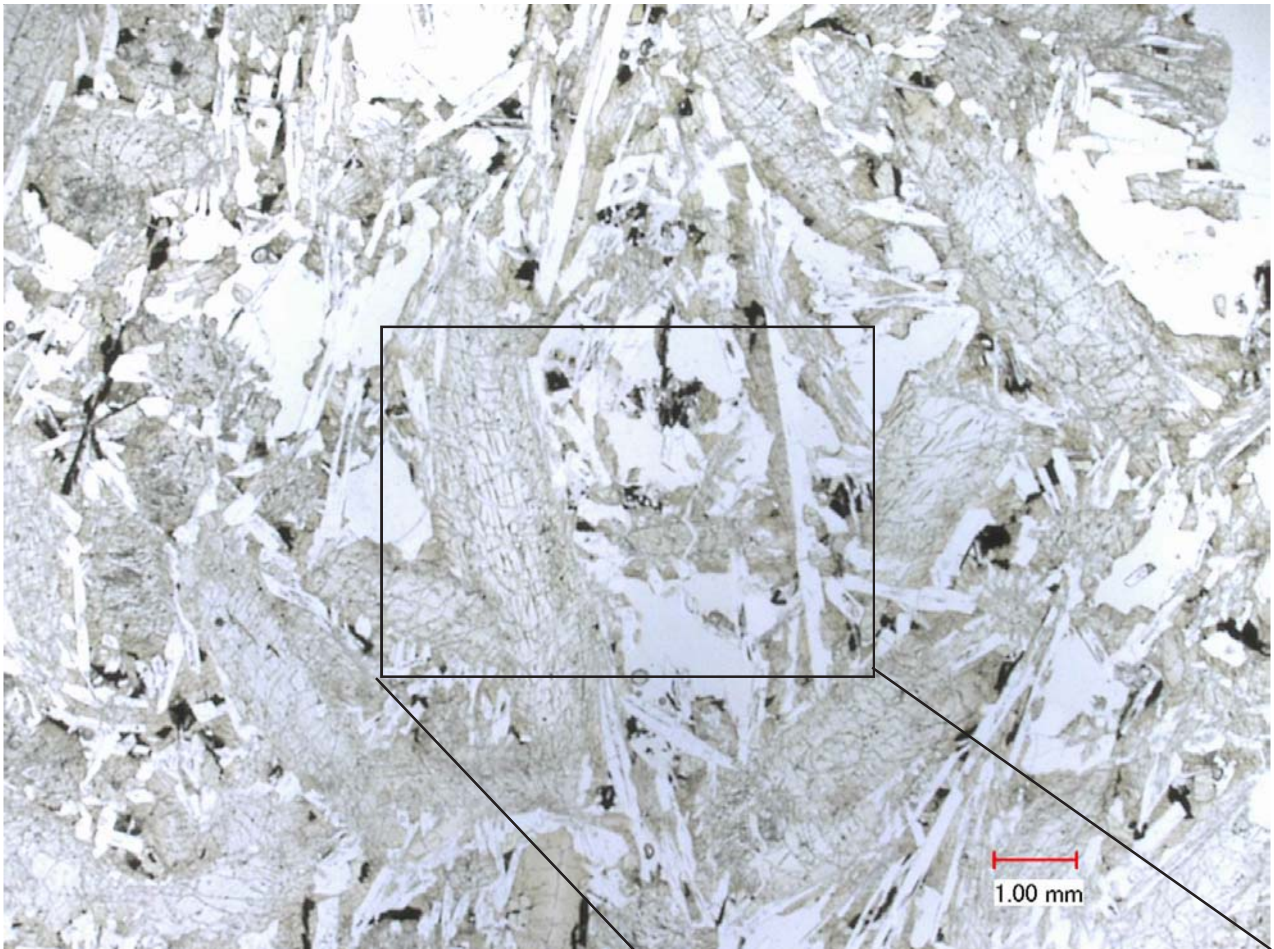

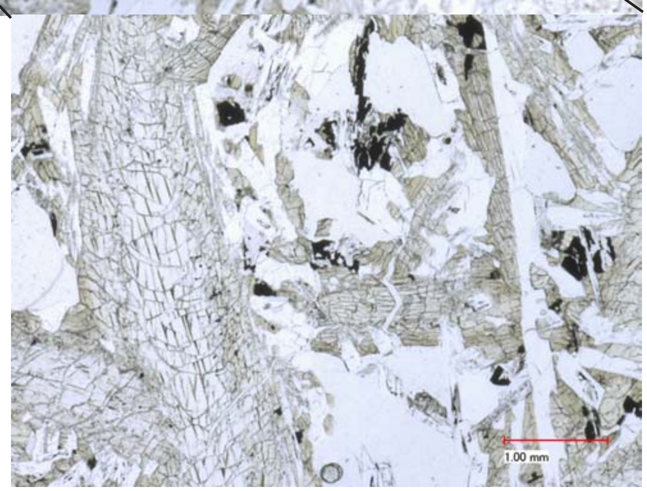

Figure 17: Photomicrographs of thin section 15058,130 by C Meyer @ 20 and 50 x.

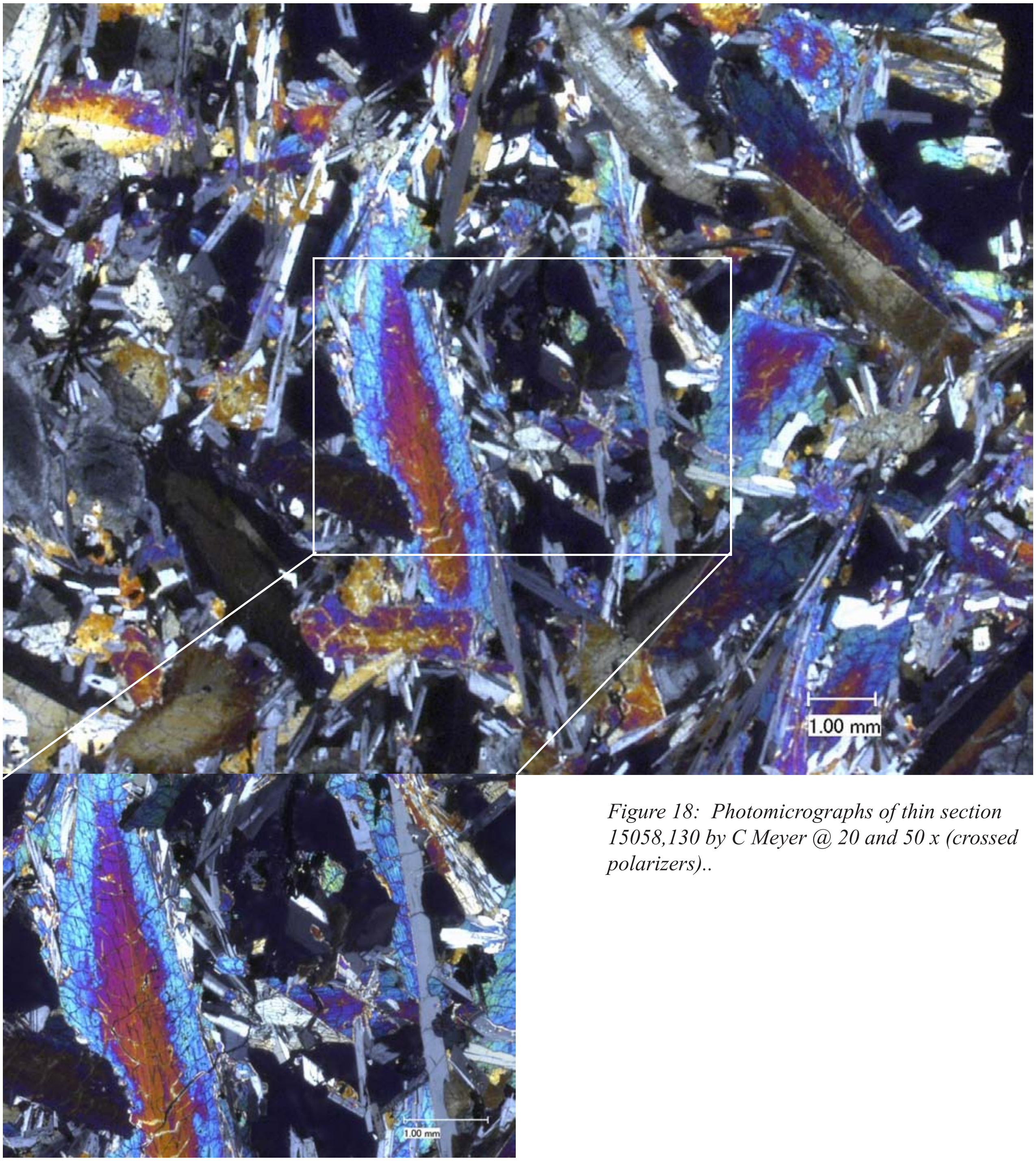

Figure 18: Photomicrographs of thin section 15058,130 by C Meyer @ 20 and 50 x (crossed polarizers)..

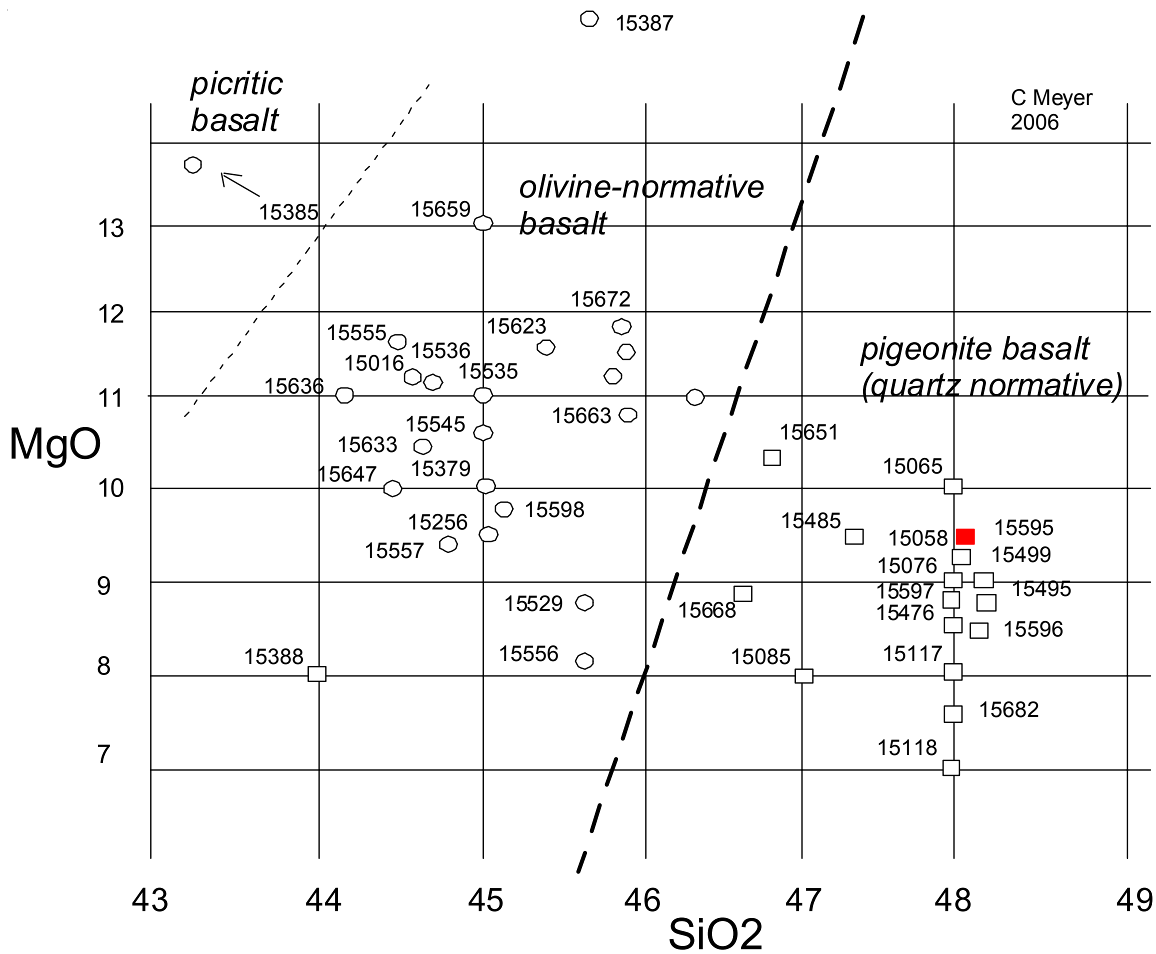

Figure 19: Apollo 15 basalts are of tw types a) pigeonite basalts and b) olivine-normative basalts (see section on 15555).